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# MANUFACTURING METHOD OF FINE HOLLOW POLYESTER FILAMENTS, FINE HOLLOW POLYESTER FILAMENTS MADE FROM THE SAME AND FINE HOLLOW POLYESTER YARNS

## Field of Invention

This invention relates to a manufacturing method of fine hollow polyester filaments and fine hollow filaments made from the same and fine hollow polyester yarns.

## Related Art

Polyester fiber is mostly used among three major synthetic fiber owing to its good mechanical features, dyeability and low cost. Manufacturing process of polyester filament is approximately as follows: polycondensation reaction of terephthalic acid and ethylene glycol to form polyester chip or melt mass, after melting, extrusion, measuring and throughput, then quenching, oil finishing and winding up. In this process, the quenching effect is very important to physical property and uniformity of yarn.

The common quenching method presently available: cross flow quenching system (as shown in figure 1). Radial out-to-in flow quenching system (as shown in figure 2). Radial in-to-out flow quenching system (as shown in figure 3). Respectively explained as follows: in cross flow quenching system, after throughput from spinneret, the filament tow is cooled one-side by quenching air; in radial out-to-in flow quenching system, after throughput from spinneret, the filament tow passing the internal part of quenching air tube, is in-to-out cooled by quenching wind along circumference of air tube; in radial in-to-out flow quenching system, after throughput from spinneret, the filament tow passing the external part of quenching air tube, is in-to-out cooled by quenching wind along circumference of air tube.

Presently among above major blowing modes, the cross flow quenching system is mostly used, the radial out-to-in flow quenching system and radial in-to-out flow quenching system are frequently applied in staple, and partly used in industrial yarn production.

Although polyester fiber has multiple merits, it lacks the merits such as softness and insulation of natural cotton and wool, while fine hollow polyester filament is generated in this way. Fine hollow polyester filament features in hand fineness, light weight and heat preservation instead of the hand harshness of general thick hollow

polyester filament.

The fine hollow polyester filaments produced in this invention adopts radial in-to-out flow quenching system at melt spinning, having d.p.f.(denier per filament) 0.3 to 2.5d, uster half inert value (u% $_{1/2}$inert) less than 0.3%, variation of thermal stress in spindles less than 4%, hollow degree from 25 to 40%. A fine hollow polyester yarn, which is produced by draw-twist texturing, air –twist texturing or one-stage direct spinning and drawing the fine hollow polyester filaments manufactured by the above manufacturing method for fine hollow polyester filaments to get fine hollow polyester yarn having d.p.f 0.2 to 1.0d, hollow degree 25 to 40% in excellent dyeability and flat surface of fabrics woven or knitted from said yarn.

**Detailed description of the invention**

Polyester hollow yarn is made into cloth and fabric to reach the purpose of light weight and thermal insulation, which is mostly popular in the market, when general polyester hollow yarn of d.p.f. greater than 1.5d is used in cloth and fabric, it feels rough and harsh in hand. There are some stripes on the fabric surface due to uneven quenching, and the use range is restricted.

Reducing d.p.f. and increasing hollow degree can be adopted to achieve the feature of light weight and thermal insulation as well as softness in polyester hollow yarn. However, generally there are two methods in reducing d.p.f., one is maintaining total throughput of polyester melt in constant amount and increasing the number of orifice on spinneret, and the other is maintaining total the number of orifice on spinneret and reducing total throughput of polyester melt.

For the quenching and blowing mode of polyester filament melt spinning quenching and blowing, cross flow quenching system is mainly adopted and supported with less out-to-in flow quenching system, of course, the quenching and blowing mode for melt spinning of existing fine hollow polyester filament also mainly use these two modes, however, if cooled with the quenching unit of cross flow quenching system, it will lead to large quenching difference between the filament tow with single face exposed to the quenching air near the wind front and the filament tow far away from wind front. Uneven quenching of filament tow, especially quenching difference increased in case of increasing the number of spinneret orifices due to the increase of the number of orifices in unit area of spinneret( orifice density), it will lead to insufficient quenching and fail to obtain the required hollow degree and uniformity. The other way aims to reduce the total throughput of polyester melt, but it usually decreases output and requires the mode of conjugate spinning, and often creates dyeing problem due to the variance of physical property in individual yarn of the

conjugate yarn.

For radial out-to-in flow quenching system, insufficient quenching of filament tow due to difficult regulation of quenching air, slow quenching air speed will lead to high uster half inert value( $u\%_{1/2}$ inert), even more seriously, the failure of smooth spinning due to the mutual adhesion among monofilament; The unstable filament tow, mutual collision of monofilament and bad process will occur due to over high quenching air speed, mutual interference in quenching air in reversed blowing direction ; Furthermore, the filament tow is uneasy to enter into narrow quenching air tube, and bad operability also adverse to the production of fine hollow polyester filament.

How to reduce d.p.f.( denier per filament) and increase hollow degree without sacrificing output, has become the subject matter that the polyester hollow yarn manufacturer anxious for, these are disclosed by such as United States patent No. 5,487,859 and European patent No.0 860 523A2. But, United States patent No. 5,487,859 did not disclose what quenching method used, and with the length of protective delay shroud from 2cm to (12 $\times$ ( d.p.f. ) $^{1/2}$) cm, due to overlong protective delay shroud, the expected hollow degree and evenness can not be achieved; besides, its hollow degree at least 10%, is far away from 25 to 40% of the expected hollow degree. The length of protective delay shroud recommended for the quenching method used in European patent No.0 860 523A2, is from 10mm to 30mm, the blowing length for the first section quick quenching zone is 80mm to 120mm, and the blowing length for the second section slow quenching zone is 150mm to 350mm. Its hollow degree is 40% to 80%, with the feature of non-deformable hollow after post processing.

Radial out-to-in flow quenching system, as stated in United States patent No. 5,536,157 and 5,866,055, is designed to produce polyester industrial yarn with d.p.f. 1.1 to 22.2d, and fails to disclose the manufacturing process for fine hollow polyester filament.

By carefully reviewing previous technologies, processing conditions and quenching units in the polyester filament manufacturing, the inventor discovers that polyester polymer with specific intrinsic viscosity and melting point, is uniformly throughput from spinneret with a multi-layer annularly arranged orifices ( the diameter difference of outermost layer orifice and the innermost orifice is set at$\leqq$ 20mm), quenched by cylindrical quenching air tube with quenching air in-to-out radial blowing, wound and packaged into filament package to accomplish this invention. This can increase the number in unit spinneret area and hollow degree of filament, uniformly distribute the hollow degree among single filament, reduce its d.p.f., and obtains fine hollow polyester filaments of excellent dyeability.

### Summary of the invention

It is an object of this invention to provide a manufacturing method for fine hollow polyester filaments, which is heating polyester polymer of inherent viscosity( IV) 0.5 ~ 0.7 and melting point of 245 ~ 265℃ to melt, filter and extruding in constant amount to obtain polyester fine hollow filaments, characterized in comprising the following steps:

a. uniformly spinning said constant amount extruded polyester melt through a multi-layer annularly arranged spinneret orifices (as shown in Fig. 5) to obtain the filament tow , wherein the diameter of outermost layer orifice is set as $D_2$ mm , and the diameter of inmost layer orifice is set as $D_1$ mm ;

b. passing said spun filament tow under spinneret through a protective delay shroud of length $L_s$ mm and a cylindrical quenching air tube of length $L_q$ mm and diameter of $D_0$ mm which offers the radial outer-flow quenching air at wind speed of 0.2- 0.6 meter / second to said filament tow from the outer side of said cylindrical quenching air tube to uniformly cooled to below glass transition point ($T_g$) of said polyester polymer for bundling;

c. said $D_2$, $D_1$, $D_0$, $L_s$, $L_q$ satisfying the following requirements:

(i) $D_2-D_1 \leqq 20$ (mm)

(ii) $12 \leqq D_1-D_0 \leqq 33$ (mm)

(iii) $2 \leqq Ls \leqq 8060 \times$ throughput (g/min) ÷( No. of filaments)$^2$ (mm)

(iv) $15 \leqq Lq \leqq 40$(cm)

d. winding said filament tow at the speed of 1800 to 4000 meter / minute.

The other object of this invention is to provide a radial out-to-in flow quenching system of enabling uniform quenching for filament tow, to produce fine hollow polyester filament. The length of protective delay shroud below spinneret is preferably set at 2 to 8060 × throughput (g/min) ÷( No. of filaments)$^2$ (mm) , when the length of protective delay shroud is less than 2(mm), the quenching air will influence surface temperature of spinneret, deteriorate production status; when the length of protective delay shroud is over 8060 × throughput (g/min) ÷( No. of filaments)$^2$ (mm) , the uster half inert value (u% $_{1/2}$inert) of fine hollow polyester filament becomes larger, even if increasing quenching air speed, it fails to meet the requirement for fine hollow polyester filament with expected hollow degree of 25 to 40%, uster half inert value( u% $_{1/2}$inert) less than 0.3%, and the finished fabric manufactured from the fine hollow polyester filament after draw texturing process, has poor dyeability itself, dyeing streak in woven fabric.

For the layout of the spinneret orifices adopted in this invention (as shown in Fig. 5) , the diameter difference of outermost layer orifice and the innermost layer orifice is

set less than 20 mm; If the diameter difference of outermost layer orifice and the innermost layer orifice is greater than 20 mm, it will lead to larger quenching air difference between the inner and external filament tow, and large difference in physical property and hollow degree among monofilament inside filament tow, and fabric in excellent dyeability can not be achieved. The distance between the diameter of innermost orifice layout and the diameter of quenching air tube is at least 12 and less than 33mm. When the distance between the diameter of innermost orifice layout and the diameter of quenching air tube is less than 12 mm, normal spinning fails due to easy touch with quenching air tube and broken; While the distance between the diameter of innermost orifice layout and the diameter of quenching air tube is greater than 33mm, it will reduce quenching efficiency in quenching air tube, and cause low hollow degree and breakage in filament due to insufficient quenching at outermost layer diameter of spinneret.

To obtain appropriate quenching for filament tow, the quenching air tube used in this invention is preferably set as 15 to 40 cm. when the length of quenching air tube is less than 15cm, the filament tow will be adhered and broken due to insufficient quenching; when the length of quenching air tube is greater than 40cm, turbulent flow will occur and deteriorate uster half inert value (u% $_{1/2}$inert); The quenching air tube used in this invention is a cylindrical shape, can be manufactured by multilayer cellulose or multilayer wire netting or filter sintered from metal or ceramic, or multilayer perforated plate ; The filament tow can be obtained by blowing quenching air uniformly out in a way of radial in-to-out from fine holes of said quenching air tube. The velocity of quenching air in this invention is preferably set as 0.2 m/sec to 0.6 cm/sec. when the velocity of quenching air is less than 0.2 m/min, the filament tow will be adhered and broken due to insufficient quenching, also accompanied by greater uster half inert value (u% $_{1/2}$inert) and smaller hollow degree. When the velocity of quenching air is greater than0.6 cm/sec, it fails to reduce the uster half inert value and do no evident improvement on uster half inert value, causing super quenching to break the filament tow.

The orifice density of spinneret layout (orifice density) is set as 7~15 orifices per square centimeter. The orifice density ( as shown in figure 5 ),is defined as the number of throughput orifices between $D_2$ ( the diameter of outermost layer orifice ) and $D_1$ ( the diameter of inmost layer orifice ) divided by area between $D_2$ and $D_1$, i.e. the number of orifices (between $D_2$ and $D_1$) $\times 4/\pi \times ( D_2{}^2 - D_1{}^2)$.

Economic benefit is reduced due to the total throughput have to be reduced in case of orifice density less than 7 holes per square centimeter in order to satisfy the requirement for d.p.f. 0.3～2.5 in this invention as well as conjugate spinning; Stable spinning fails due to large uster half inert value (u%$_{1/2}$inert), quenching difference

among monofilament caused by compact layout among monofilament in case of orifice density exceeding 15 orifices per square centimeter.

The inherent viscosity (IV) of polyester chip used in this invention is between 0.5 to 0.7, after melting, the polyester chip is extruded from spinneret to spin to form filament, then is subject to drawing, quenching, oil finishing and winding to get the fine hollow polyester filament. The fine hollow polyester filament produced has elongation at break between 70% to 180%, d.p.f. of 0.3 to 2.5, and hollow degree of 25 to 40% , uster half inert value (u% $_{1/2}$inert) less than 0.3%; variation of thermal stress in spindles less than 4%. Consequently, fine hollow polyester yarn with excellent dyeability and d.p.f. of 0.2 to 1.0, hollow degree of 25 to 40% can be achieved after draw texturing such as draw twisting, air twisting or one stage direct spin drawing process (spin draw).

## Analytical procedures

a. Hollow degree: taking pictures with 800 times commercial optical microscope, then magnifying 2 times with photocopier. Take 10 sections every time, respectively cut down the hollow section and solid section with scissor , then weigh.

Hollow degree ( % ) = weight of solid section ÷ (weight of hollow section+ weight of solid section) × 100%

b. Variation of thermal stress in spindles:

Analytical apparatus:

Textechno Dynafil M Type DPG / M

Analysis condition:

Draw ratio 1.6, heating temperature 150℃, analyzing speed 50M, analyzing time 1min.

By sampling specimens from a cake for every doffing to be tested, analyzing the thermal stress according to the above mentioned conditions, variation of thermal stress in spindles can be calculated by using instrument.

c. Uster half inert value (u% $_{1/2}$ inert):

Analytical apparatus:

USTER TESTER 3

Analyzing speed: 400m/min, analyzing time: 2.5 min

Analyzing length: 1000m

By sampling specimens from a cake for every doffing to be tested, analyzing the uster half inert value according to the above mentioned conditions, uster half inert value (u% $_{1/2}$ inert) can be calculated by using instrument.

d. d.p.f. ( denier per filament ) :

Winding filament tow 90 loops, weighing (weight shown in a gram), multiply a with100 to get total denier b of filament tow. The b is divided by c, the number of filament in filament tow to get d.p.f. ( denier per filament ) .

e. Tensile strength of elongation at break:

Analytical apparatus:

Textecho Type FPA / M

Analyzing condition: analyzing length 10 centimeters, drawing rate 60cm/ min. pre-load 0.5cN/tex. The strength is the maximum strength, and the corresponding elongation is elongation at break.

f. Dyeability:

Fabric texture: satin is woven by 75d / 36f textured yarn in warp with warp density of 150 strip per inch, and weft yarn manufactured by this invention with weft density regulated in d.p.f.

Dyeing and finishing condition: using disperse dyestuff to dye for 130℃ × 130min, after drying the dyed and finished fabric, checking if striation exists across wary under natural light.

Striation grade:

Excellent (○): Dyed and finished fabric has uniform gloss at the surface under natural light

Fair (△): Dyed and finished fabric has little degree of short chatter( less than 1 centimeter) under natural light.

Streak ( × ): Dyed and finished fabric has long chatter( greater than 1 centimeter) under natural light.

g. Boiling water shrinkage:

Winding for 20 loops( 20 meters) with hank reeling machine, and 1g / den load hung below the filament tow, then recording the length a ( cm)on square paper, and adequately binding the sample yarn, putting into 100℃ boiling water for 30 minutes, loosing the hung 1g / denier load, measuring the length b to calculate boiling water shrinkage as follows.

Boiling water shrinkage = (initial length of sample - length after shrinkage) ÷ initial length of sample × 100%

## Brief description of the drawings

Fig. 1 shows a schematic diagram of a conventional cross flow quenching system;

Fig. 2 shows a schematic diagram of a known radial out-to-in flow quenching

system;

Fig. 3 shows a schematic diagram of a radial in-to-out flow quenching system used in this invention;

Fig. 4 shows a schematic diagram of cylindrical quenching air tube of a radial in-to-out flow quenching system used in this invention;

Fig. 5 shows a layout of orifices of spinneret used in this invention;

Fig. 6 shows a draw twister for draw texturing used in this invention;

Fig. 7 shows a schematic diagram of direct spin draw in a radial in-to-out flow quenching system used in this invention.

In the conventional cross flow quenching system shown in Fig. 1, quenching air is blown from one side to the filament tow throughput from the spinneret to cool said filament tow.

In the known radial out-to-in flow quenching system shown in Fig. 2, quenching air is blown radially from the wall of quenching air tube that surround the filament tow throughput from the spinneret, quenching air is blown to the center portion of said filament tow all around from said filament tow to cool said filament tow.

In the radial in-to-out flow quenching system used in this invention shown in Fig. 3, quenching air is blown radially from the wall of quenching air tube that locate at the center portion of the filament tow throughput from the spinneret, quenching air is blown to the surrounding of said filament tow from the center portion of said filament tow to cool said filament tow.

In the process of the radial in-to-out flow quenching system shown in Fig.4, the quenching air tube has length Lq and outer diameter Do.

In the process of the radial in-to-out flow quenching system shown in Fig. 3, the spinneret used is shown as Fig. 5.

The fine hollow polyester filament 10 manufactured from the process of the radial in-to-out flow quenching system shown in Fig. 3 ， is drawn by the draw twister shown in Fig. 6 to get fine hollow polyester yarn 14.

In the process of the radial in-to-out flow quenching system used in this invention shown in Fig. 7, quenching air is blown radially from the wall of quenching air tube that locate at the center portion of the filament tow throughput from the spinneret, quenching air is blown to the surrounding of said filament tow from the center portion of said filament tow to cool said filament tow.

Numerals used in the drawings are meant as follows.

1 polyester melt
2 spinning head
3 spinneret
33 orifice

4 filament tow
5 quenching air tube
6 oiling nozzle
7 filament tow after bundling
8 non-heating roller
8-1 heating roller
8-2 heating roller
8-3 separating wheel
9 winding machine
10 fine hollow polyester filament cake
11 heating roller
12 heater
13 heating roller
14 fine hollow polyester yarn package

**Example and comparative example**

In table 1, radial in-to-out flow quenching system (as shown in figure 3) is used in example of this invention, cross flow quenching system (as shown in figure 1) is used in comparative example 1, and radial out-to-in flow quenching system (as shown in figure 2) is used in comparison example 2.Uster half inert value (u% $_{1/2}$inert), hollow degree and variation of thermal stress in spindles of the fine hollow polyester filaments obtained in example 1 of this invention evidently superior to that of comparative example 1 and 2. After draw texturing process, it is known from table 2 that the fine hollow polyester yarn obtained in example 1 has excellent dyeability and no dyeing streak in woven fabric.

In Example 2, under the processing conditions such as: the length of a protective delay shroud of 8 mm, the length of quenching air tube of 35 cm, fine hollow polyester filaments of d.p.f. 0.8 , uster half inert value (u% $_{1/2}$inert) 0.29%, hollow degree 30%, and variation of thermal stress in spindles 3.4% can be obtained After draw texturing process, the fine hollow polyester yarn of d.p.f. .052, hollow degree 29% and no dyeing streak in woven fabric can be obtained.

Table 1

| | Item Example | Example 1 | Example 2 | Comparative Example 1 | Comparative Example 2 |
|---|---|---|---|---|---|
| Spinning Condition | IV of polyester chip | 0.64 | .064 | .064 | .064 |
| | Dowtherm temperature (℃) | 296 | 300 | 296 | 296 |
| | Throughput (g/min) | 31.9 | 21.3 | 15.3 | 31.9 |
| | Length of protective delay shroud Ls(mm) | 14 | 8 | 55 | 45 |
| | quenching mode | Radial in-to-out flow quenching | Radial in-to-out flow quenching | Cross flow quenching | Radial out-to-in flow quenching |
| | Length of quenching air tube Lq (cm) | 40 | 35 | 120 | 50 |
| | Diameter of quenching air tube $D_0$ (mm) | 30 | 30 | -- | 85 |
| | Quenching air velocity (m/sec) | 0.35 | .030 | 0.80 | 0.30 |
| | Quenching air temperature (℃) | 21 | 21 | 21 | 21 |
| | Orifice density (orifice/$cm^2$) | 11 | 11 | 2 | 5 |
| | Orifice of spinneret | 100 | 100 | 48 | 100 |
| | Diameter of innermost layer orifice $D_1$(mm) | 49 | 49 | 12 | 20 |
| | Diameter of outermost layer orifice $D_2$(mm) | 61 | 61 | 54 | 56 |
| | Winding velocity (m/min) | 2500 | 2500 | 2500 | 2500 |
| Physical Properties Of Fine Hollow Polyester Filaments | d.p.f. (den) | 1.1 | 0.8 | 1.1 | 1.1 |
| | Tensile strength (g/den) | 2.96 | 3.01 | 2.80 | 2.90 |
| | Elongation at break (%) | 120 | 118 | 115 | 120 |
| | uster half inert value ($u\%_{1/2}$inert) | 0.28 | 0.29 | 0.70 | 0.45 |
| | Hollow degree (%) | 32 | 30 | 20 | 21 |
| | Variation of thermal stress in spindles (%) | 3.5 | 3.4 | 8.0 | 7.0 |

Table 2

| Drawing Condition | Example / Item | Example 1 | Example 2 | Comparative Example 1 | Comparative Example 2 |
|---|---|---|---|---|---|
| | Machine Type | Teijin DT-210 | Teijin DT-210 | Teijin DT-210 | Teijin DT-210 |
| | Draw Ratio | 1.54 | 1.52 | 1.45 | 1.54 |
| | Velocity (m/min) | 720 | 720 | 720 | 720 |
| | Heating Temperature of Roller (℃) | 85 | 85 | 85 | 85 |
| | Heating Temperature of Hot Plate (℃) | 210 | 210 | 210 | 210 |
| Physical Properties Of Filament | d.p.f. (den) | 0.71 | 0.52 | 0.74 | 0.74 |
| | Tensile Strength (g/den) | 3.60 | 3.62 | 3.50 | 2.55 |
| | Elongation (% ) | 29 | 29 | 29 | 29 |
| | Hollow Degree (% ) | 30 | 29 | 19 | 19 |
| | Boiling Water Shrinkage (% ) | 8 | 7.5 | 8 | 8 |
| | Dyeability of woven fabrics | excellent (○) | excellent (○) | streak ( x ) | fair (△) |